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Age and Sex Differences in Balance Outcomes among Individuals with Chronic Obstructive Pulmonary Disease (COPD) at Risk of Falls

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ABSTRACT

No previous research has examined age and sex differences in balance outcomes in individuals with chronic obstructive pulmonary disease (COPD) at risk of falls. A secondary analysis of baseline data from an ongoing trial of fall prevention in COPD was conducted. Age and sex differences were analyzed for the Berg Balance scale (BBS), Balance Evaluation System Test (BEST test) and Activities-specific Balance Confidence Scale (ABC). Overall, 223 individuals with COPD were included. Females had higher balance impairments than males [BBS: mean (SD) = 47 (8) vs. 49 (6) points; BEST test: 73 (16) vs. 80 (16) points], and a lower confidence to perform functional activities [ABC = 66 (21) vs. 77 (19)]. Compared to a younger age (50–65 years) group, age >65 years was moderately associated with poor balance control [BBS ($r = -0.37$), BEST test ($r = -0.33$)] and weakly with the ABC scale ($r = -0.13$). After controlling for the effect of balance risk factors, age, baseline dyspnea index (BDI), and the 6-min walk test (6-MWT) explained 38% of the variability in the BBS; age, sex, BDI, and 6-MWT explained 40% of the variability in the BEST test; And BDI and the 6-MWT explained 44% of the variability in the ABC scale. This study highlights age and sex differences in balance outcomes among individuals with COPD at risk of falls. Recognition of these differences has implications for pulmonary rehabilitation and fall prevention in COPD, particularly among females and older adults.

ABBREVIATIONS:

ABC: activity specific balance confidence scale; BBS: Berg balance scale; BEST test: balance evaluation system test; BMI: body mass index; COPD: chronic obstructive pulmonary disease; FVC: forced vital capacity; 6-MWT: 6-min walk test; PR: pulmonary rehabilitation

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Introduction

The prevalence of Chronic obstructive pulmonary disease (COPD) is increasing rapidly in females than males [1, 2], with the highest female prevalence found in North America and in urban settings [2]. Furthermore, COPD is more prevalent in individuals who are ≥ 60 years [1]. Several studies have suggested that symptoms, pulmonary function, exacerbation frequency and comorbidities vary with age and sex in individuals with COPD [3–9]. Females < 65 years have more severe dyspnea [3–6], airflow limitation [7], and exhibit a higher risk of exacerbations [7–9] but have better forced expiratory volume in 1 s (FEV_1) [8] than males with COPD.

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With respect to comorbidities, males with COPD have a higher risk of developing ischemic heart disease [6, 10, 11], while osteoporosis [6, 10, 11], anxiety and depression [3, 5, 6] are more frequent in females. Older adults with COPD have increased risk of cardiovascular diseases, osteoporosis, fractures, as well as depression and anxiety [12]. In particular, females > 65 years with COPD have lower exercise tolerance [9, 13] and multiple comorbidities [14]. Interestingly, females have a greater 5-year survival than males (87% vs. 76%) with COPD [8].

Advanced age, female sex, and deficits in balance control are all associated with an increased risk of falls [15–18], attributed to decreased levels of physical activity [16], muscle weakness [16], altered trunk muscle mechanics [15] and somatosensory deficits [19]. Such functional limitations can lead to activity avoidance, reduced activities of daily living, social isolation, depression, and decreased health-related quality of life, all of which impact the management of COPD [20].

Balance training combined with pulmonary rehabilitation (PR) and fall prevention programs improves balance impairments [21, 22], health-related quality of life, fatigue, and mental health [23] and reduces the risk of falls in COPD [18]. However, despite these balance training benefits, balance impairments persisted in patients with acute exacerbation of COPD (AECOPD) after one-month of training compared to patients without AECOPD [24]. The declined balance in AECOPD may need adjusting balance training programs to maximize training benefits in patients with AECOPD. Similarly, potential age and sex differences in balance impairments in individuals with COPD may require clinicians to modify balance training parameters (duration, intensity, & frequency) for optimizing treatment effects and obtaining better outcomes.

As noted earlier, age and sex differences were detected in several demographical, physiological, and functional outcomes in individuals with COPD, which are reported to affect therapeutic approaches to individuals with COPD [6, 25]. To our knowledge, no previous study assessed age and sex differences in balance outcomes in individuals with COPD. Therefore, this study explores the association of age and sex differences on balance outcomes among individuals with COPD who are at risk of falling. We hypothesized that females and older adults have higher balance deficits than males and younger individuals with COPD.

Methods

Study design and participants

This study was reported in accordance with the STrengthening the Reporting of OBservational studies in Epidemiology (STROBE) [26]. A secondary analysis of baseline data from an ongoing randomized controlled trial (RCT) that is investigating the effect of pulmonary rehabilitation combined with balance training on fall reduction in individuals with COPD was conducted (https://clinicaltrials.gov/ct2/show/NCT02995681) [27]. Ethics approval was received for the RCT protocol at all participating sites, and informed consent was obtained from all participants. A full description of the recruitment process and data collection is described in the published protocol [27].

Participants were included in this study if they meet the following inclusion criteria: (1) aged 50 years or more; (2) had a confirmed clinical diagnosis of COPD using a spirometry test based on the Global Initiative for Chronic Obstructive Lung Disease (GOLD) criteria—postbronchodilator FEV_1/forced vital capacity (FVC) ratio < 70%; (3) reported a history of falls or balance problems; and (4) completed baseline balance measures including the Berg Balance Scale (BBS) [28], the Balance Evaluation System Test (BEST test) [29], and Activity specific Balance Confidence scale (ABC) [30].

Clinical and physiological characteristics of 223 individuals with COPD [age, sex, body mass index (BMI), smoking history, oxygen use, spirometry, presence of comorbid conditions, six-min walk test (6-MWT), Baseline Dyspnea Index (BDI), and number of falls at one and two years] were retrieved from baseline study data. Balance outcomes were compared in male and female, adults (50-65 years) and older adults (> 65 years) [31]. The severity of dyspnea was determined by the number of oxygen users and the BDI score (total score =12, 12 meaning no dyspnea) [32].

Balance outcome measures

Balance was assessed using the BBS, BEST test, and ABC scale [28–30]. The BBS assesses 14 tasks such as transfers, reaching, turning around and single-legged standing and has a total score of 56 points, with higher scores indicating better balance [28]. The BBS is a valid [$r = 0.53–0.75$] and reliable [Interrater correlation coefficient (ICC) = 0.94] measure of balance control [33]. The minimal clinically important difference (MCID) value for the BBS is a change of 5-7 points [34] and the Minimal Detectable change (MDC) value is found to be 5.9 points in one study [33] and 3.5 in another study [35].

The BEST test assesses six subsystems of balance control: biomechanics, stability limits/verticality, anticipatory postural adjustments, postural responses, sensory orientation, and stability during gait [29]. It consists of 27 tasks with some items consisting of two sets of four subitems (for left and right sides), equaling a total of 36-items. Each item is scored on a 4-level, ordinal scale from zero (worst performance) to three (best performance). Scores for the test and each section are provided as a percentage of total points ranging from 0 – 100%. The BEST test is a valid [$r = 0.64$] and reliable [ICC = 0.85] measure of balance control [33]. The MCID value for the BEST test is a change of 13-17 points [34] and the MDC value is 6.3 points [33].

The ABC scale requires participants to indicate their confidence performing 16 functional activities without losing their balance. The total score ranges from 0% to 100%, with higher scores indicating greater balance confidence [30]. The ABS scale, is a valid [$r = 0.75$] measure of balance confidence [33]. The MCID value for the ABC scale is a change of 19 points [34] and the MDC is 8.3% [35].

Table 1. Clinical and physiological characteristics of individuals with COPD.

Variable	Male $N=123$	Female $N=100$	Adults (50–65 years) $N=47$	Older adults (> 65 years) $N=176$	All participants $N=223$
Age, year	73 ± 8	71 ± 9	60 ± 4	75 ± 6	72 ± 9
Sex, *N* (%)					
Males	–	–	20 (43)	103 (59)	123 (55)
Females			27 (57)	73 (41)	100 (45)
BMI, kg/m^2	27 ± 5	28 ± 6	29 ± 6	27 ± 6	28 ± 6
Smoking, pack/year	52 ± 47	41 ± 22	45 ± 36	47 ± 39	47 ± 38
Have comorbidities, *N* (%)					
Diabetes	26 (21)	16 (16)	5 (11)	37 (21)	42 (19)
Cardiac disease	47 (38)	31 (31)	11 (23)	67 (38)	78 (35)
Hypertension	58 (47)	35 (35)	12 (26)	81 (46)	93 (42)
Anxiety and depression	12 (10)	20 (20)	10 (21)	22 (13)	32 (14)
Dyslipidemia	38 (31)	17 (17)	7 (15)	48 (27)	55 (25)
GERD	11 (9)	16 (16)	7 (15)	20 (11)	27 (12)
MSK conditions	66 (54)	72 (72)	25 (53)	113 (64)	138 (62)
Falls History					
Falls in the last year	0.60 ± 0.8	0.88 ± 0.8†	0.74 ± 0.9	0.87 ± 0.9	0.73 ± 0.8
Falls in the last 2 years	0.78 ± 0.8	1.1 ± 0.9†	0.72 ± 0.8	0.91 ± 0.9	0.90 ± 0.9
Spirometry	$N=76$	$N=49$	$N=29$	$N=96$	$N=125$
FEV1, L	1.55 ± 0.7	1.16 ± 0.6†	1.42 ± 0.7	1.39 ± 0.7	1.40 ± 0.7
FEV1% predicted	51.4 ± 17, $N=104$	53.2 ± 17, $N=75$	50.9 ± 16, $N=47$	52.6 ± 17, $N=132$	52.1 ± 17, $N=180$
FVC, L	3.15 ± 0.9	2.19 ± 0.6†	2.74 ± 0.8	2.78 ± 0.9	2.77 ± 0.9
FVC % predicted	76.8 ± 22	79.9 ± 22	75.2 ± 17	78.9 ± 23	78 ± 22
FEV1/FVC, ratio	0.49	0.52	0.52	0.51	0.51
Oxygen use, N (%)					
Yes	13 (11)	23 (23)†	8 (17)	26 (15)	34 (15)
No	110 (89)	77 (77)	39 (83)	150 (85)	189 (85)
BDI, points out of 12	7 ± 3	6 ± 2†	6 ± 3	6 ± 3	6 ± 2
6-MWT, m	336 ± 163	272 ± 129†	363 ± 191	292 ± 135†	307 ± 151
%PV, 6-MWT	53.5 ± 24	42.8 ± 20†	–	–	48.8 ± 23

Note: Descriptive statistics were used to describe the clinical and physiological characteristics of individuals with COPD. Continuous data are presented as mean and standard deviation (SD). Categorical data are presented as number and percentage (%).

Independent *t*-test was used to detect differences in age and sex groups for the variables: BDI, Spirometry, falls history, and 6-MWT. Chi-square test was used to detect differences between groups for the oxygen use.

†Significant difference between groups, $p<0.05$.

Abbreviations: COPD: chronic obstructive pulmonary disease; N: sample size; BMI: body mass index; GERD: Gastroesophageal Reflux Disease; MSK: musculoskeletal, BDI: baseline dyspnea index, FEV_1: forced expiratory volume at 1 s; FVC: forced vital capacity; 6-MWT: 6-min walk test, %PV: percentage of predicted value of the 6-MWT.

Assessment of exercise tolerance

Exercise tolerance was assessed using the 6-MWT. Patients walk for six minutes, attempting to cover as much distance as possible within the time allotted. The distance covered is measured in meters [36]. A detailed description of the test is published [37]. The test has been shown to be valid and reproducible [38] and has been previously used to assess exercise tolerance in COPD [39]. In average, healthy adults aged 40–80 years can walk 571 m (range, 380–782 m) [13].

The expected value of the 6-MWT was calculated using the equation proposed by Troosters [40] as follows: Predicted 6MWT = 218 + 5.14 * height (cm) – 5.32 * age (years) – 1.8 * weight (kg) + 51.31 * sex. Then, the percentage of the predicted value of the 6-MWT was calculated by dividing the absolute value of the 6-MWT by the predicted value of 6-MWT and then multiplying by 100 as follows: Absolute 6-MWT/predicted 6-MWT * 100.

Statistical analysis

Statistical analyses were performed using SPSS® (version 27, Chicago, IL, USA). A *P* value of < 0.05 was considered statistically significant. Descriptive statistics were used to report the clinical and physiological variables (age, BMI, smoking history, and comorbidities). An independent *t*-test was used to detect differences in age and sex groups for the number of falls in the last one and two years, spirometry data, the 6-MWT (absolute and % of predicted values), and BDI. A chi-square test was used to detect differences between groups for oxygen use. One-way ANOVA was used to detect differences in balance outcomes (BEST test, BBS, and ABC) based on age groups (adults: 50–65, older adults > 65 years) and sex (male, female). Pearson's correlation coefficients (*r*) were calculated between balance measures and risk factors. The relationship strength of the correlations were classified as follows: $0.1 \le r < 0.3$ = weak association, $0.3 \le r < 0.5$ = moderate association, $r \ge 0.5$ = strong association [41]. A multivariable regression analysis was run to examine the effect of age (continuous variable) and sex (male, female) on balance measures (BBS, BEST test, ABC scale) at baseline. A second multivariable regression analysis was run to examine how other risk factors modulate the effect of age and sex on balance outcomes. Risk factors that had significant correlations with balance measures (Table 3) were included in the regression analyses.

Table 2. Age and sex differences in balance outcomes in individuals with COPD ($n = 223$).

Variable	Adults (50–65 years)	Older adults (> 65 years)	*P* value	Males	Females	*P* value	All participants
BBS, points	51 ± 4 (49–52)	48 ± 8 (46–49)	0.009	49 ± 6 (48–50)	47 ± 8 (45–49)	0.02	48 ± 7 (47–49)
BEST test							
I. Biomechanics, points	10 ± 3 (9–11)	9 ± 3 (8–9)	0.002	9 ± 3 (9–10)	9 ± 3 (8–9)	NS	9 ± 3 (9–10)
Biomechanics, %	68 ± 19 (62–74)	57 ± 21 (54–60)	0.002	62 ± 23 (58–66)	57 ± 18 (54–61)	NS	60 ± 22 (57–63)
II. Stability limits/ verticality, points	17 ± 2 (16–18)	16 ± 3 (16- 17)	NS	17 ± 3 (16–17)	16 ± 3 (15–16)	0.003	16 ± 3 (16–17)
Stability limits/verticality, %	81 ± 10 (78–84)	78 ± 13 (76–80)	NS	81 ± 12 (78–83)	76 ± 13 (73–78)	0.003	78 ± 13 (77–80)
III. Anticipatory postural adjustment, points	13 ± 3 (13–14)	12 ± 3 (11–12)	0.003	13 ± 3 (12–13)	12 ± 3 (11–12)	0.03	12 ± 3 (12–13)
Anticipatory postural adjustment, %	74 ± 15 (70–79)	65 ± 19 (62–68)	0.003	71 ± 17 (67–73)	64 ± 19 (61–68)	0.03	68 ± 19 (65–70)
IV. Postural responses, points	13 ± 4 (12–15)	12 ± 5 (11–13)	NS	13 ± 5 (13–14)	11 ± 5 (10–12)	0.001	12 ± 5 (12–13)
Postural responses, %	74 ± 25 (66–81)	67 ± 27 (63–71)	NS	74 ± 25 (70–79)	62 ± 26 (56–67)	0.001	69 ± 27 (65–72)
V. Sensory orientation, points	13 ± 2 (12–14)	12 ± 3 (11–12)	NS	13 ± 3 (12–13)	12 ± 3 (11–12)	0.04	12 ± 3 (12–13)
Sensory orientation, %	85 ± 16 (81–89)	79 ± 21 (76–83)	NS	83 ± 18 (80–87)	78 ± 22 (73–82)	0.04	81 ± 21 (78–83)
VI. Stability during gait, points	16 ± 4 (15–17)	14 ± 5 (13–15)	0.02	15 ± 4 (14–16)	14 ± 5 (13–15)	0.02	14 ± 5 (14–15)
Stability during gait, %	75 ± 18 (70–80)	67 ± 22 (64–70)	0.02	72 ± 21 (68–76)	65 ± 22 (60–70)	0.02	69 ± 23 (66–72)
Total, points	82 ± 14 (78–86)	75 ± 19 (72–77)	0.01	80 ± 16 (77–83)	73 ± 16 (70–76)	0.003	77 ± 17 (74–79)
Total, %	76 ± 13 (72–79)	69 ± 16 (67–72)	0.01	74 ± 15 (71–76)	68 ± 15 (65–71)	0.003	71 ± 15 (69–73)
ABC, %	71 ± 21 (65–77)	72 ± 21 (69–75)	NS	77 ± 19 (74–81)	66 ± 21 (61–70)	0.001	72 ± 21 (69–75)

Note: One-way ANOVA was used to detect differences in balance outcomes based on age and sex. Data are presented as mean ± SD and 95% confidence intervals (95% CI).

Abbreviations: COPD: chronic obstructive pulmonary disease; N: sample size; BBS: Berg balance scale; BEST test: balance evaluation system test; ABC: Activities-specific Balance Confidence Scale; CI: confidence intervals, NS: nonsignificant.

Results

Clinical and physiological characteristics

Analyses of the clinical and physiological characteristics were completed for 223 individuals with COPD (123 male, 100 female). On average, participants were 72 ± 9 years of age, with a mean BMI of 28 ± 6 kg/m^2. Females significantly used more oxygen [$N = 23$ for female vs. 13 for male, $p < 0.05$], had lower FEV_1 [Mean difference (MD) = 0.39 L, $p < 0.05$], FVC [MD = 0.96 L, $p < 0.05$], BDI [MD = 1 point, $p < 0.05$], and exercise tolerance [Absolute (MD = 64 m) & % of Predicted value (MD = 11%) of the 6-MWT, $p < 0.05$], and higher number of falls in the last one [MD = 0.3-point, $p < 0.05$] and two [MD = 0.3-point, $p < 0.05$] years, than males with COPD.

Older adults (> 65 years) had significant lower exercise tolerance [MD = 71 m, $p < 0.05$] than adults (50–65 years). A summary of the clinical and physiological characteristics between adults and older adults and between males and females is presented in Table 1.

Balance outcomes – age and sex differences

Significant differences in balance outcomes were detected between the two age groups. Adults > 65 years had worse scores in three out of the six BEST test subcategories including: body biomechanics, anticipatory postural adjustments, and stability in gait, and worse overall balance compared to adults ≤65 years with COPD as detected by the BBS [MD = 3 points, $p < 0.009$] and BEST test total score [MD = 7 points, $p < 0.01$] (Table 2).

Significant differences in balance outcomes were also detected between males and females with COPD. Females had poorer scores in all BEST test subcategories except biomechanics, worse overall balance, and less confidence to perform balance-related activities compared to males as detected by the BBS [MD = 2 points, $p < 0.02$], BEST test total score [MD = 7 points, $p < 0.003$] and ABC scale [MD = 10 points, $p < 0.001$] (Table 2).

Associations with balance outcomes

Associations of age and balance outcomes

Pearson's correlations revealed significant negative and moderate associations between age and BBS scores ($r = -0.37$, $p < 0.001$), BEST test score ($r = -0.33$, $p < 0.001$), and negative and weak association with the ABC scale ($r = -0.13$, $p < 0.03$), indicating that overall balance, and confidence to perform balance-related activities decline with aging.

Associations of sex and balance outcomes

Pearson's correlations revealed significant negative and weak associations between sex and BBS scores ($r = -0.17$, $p < 0.001$), BEST test score ($r = -0.22$, $p < 0.001$), and ABC scale ($r = -0.29$, $p < 0.001$), indicating that females with COPD have poorer overall balance and less confidence to perform balance-related activities than males with COPD.

Associations of other risk factors and balance outcomes

Pearson's correlations revealed significant positive and strong correlations for the BDI with the ABC scale ($r = 0.50$, $p < 0.001$), and for the 6-MWT with the BBS ($r = 0.50$, $p < 0.001$), BEST test ($r = 0.54$, $p < 0.001$), and ABC scale

Table 3. A summary of significant Pearson's correlations of risk factors and balance measures in individuals with COPD.

Variables	BBS, points *P*-value	BEST test, % *P*-value	ABC scale, % *P*-value
Age	−0.37, < 0.001	−0.33, < 0.001	−0.13, = 0.03
Sex, male	−0.17, < 0.001	−0.22, < 0.001	−0.29, < 0.001
BDI	0.43, < 0.001	0.44, < 0.001	0.50, < 0.001
6-MWT	0.50, < 0.001	0.54, < 0.001	0.54, < 0.001
Falls in the last year	−0.21, < 0.001	−0.23, < 0.001	−0.29, < 0.001
Falls in the last two years	−0.27, < 0.001	−0.28, < 0.001	−0.30, < 0.001
FVC, L		0.17, = 0.007	0.34, < 0.001
FVC%			0.16, = 0.009
Have Cardiac disease		−0.13, = 0.03	
Have Hypertension			0.13, = 0.03
Have Dyslipidemia			0.18, = 0.004
Have GERD			0.13, = 0.04
Have MSK condition			−0.18, = 0.005

Abbreviations: COPD: chronic obstructive pulmonary disease BBS: Berg balance scale; BEST test: balance evaluation system test; ABC: Activities-specific Balance Confidence Scale, NS: non-significant, FVC: forced vital capacity, GERD: Gastroesophageal Reflux Disease; MSK: musculoskeletal, BDI: baseline dyspnea index, 6-MWT: 6-min walk test.

($r = 0.54$, $p < 0.001$). A summary of all significant Pearson's correlations is presented in Table 3.

Predictors of balance outcomes

A summary of the regression models is presented in Table 4. In the first model, age and sex were significant predictors of the BBS, BEST test, and the ABC scale ($p < 0.001$). Males had higher BBS [B (SE) = −3.2 (0.88), $p < 0.001$] and BEST test [B (SE) = −12.3 (2.7), $p < 0.001$] scores than females, and with nine-year increase in age, BBS scores decreased by 3 points [B (SE) = −0.34 (0.05), $p < 0.001$] and BEST test decreased by 3.5% [B (SE) = −0.39 (0.16), $p = 0.014$]. Males also had higher balance confidence than females [B (SE) = −12.3 (2.7), $p < 0.001$], and with nine-year increase in age, the ABC score decreased by 3.5% [B (SE) = −0.39 (0.16), $p = 0.014$]. Together, age and sex explained 19%, 17% and 10% of the variability in BBS, BEST test, and the ABC scores, respectively (Table 4).

After controlling for the effect of other balance risk factors, age, BDI, and the 6-MWT were significant predictors of the BBS ($p < 0.001$). With each nine-year increase in age, BBS scores decreased by 2 points [B (SE) = −0.23 (0.05), $p < 0.001$], with each two scores increase in the BDI, BBS scores increased by 1.5 points [B (SE) = 0.73 (0.18), $p < 0.001$], and with each 30 m increase in the 6-MWT, BBS scores increased by 0.39 points [B (SE) = 0.013 (0.003), $p < 0.001$]. Together, age, BDI, and the 6-MWT explained 38% of the variability in the BBS scores.

For the BEST test, age, sex, BDI, and the 6-MWT were significant predictors. Males had higher BEST test scores than females [B (SE) = −4.51 (1.9), $p = 0.02$], with each nine-year increase in age, BEST test score decreased by 3.4% [B (SE) = −0.38 (0.10), $p < 0.001$], with each one score increase in BDI, BEST test scores increased by 1.5% [B (SE) = 1.5 (0.38), $p < 0.001$], and with each 30 m increase in the 6-MWT, BEST test scores increased by 1.2% [B (SE) = 0.04 (0.01), $p < 0.001$]. Together, age, sex, BDI, and the 6-MWT explained 40% of the variability in the BEST test scores. And for the ABC sale, BDI and the 6-MWT were significant predictors. With each one score increase in the BDI, ABC scale scores increased by 2.4% [B (SE) = 2.4 (0.53), $p < 0.001$], and with each 30 m increase in the 6-MWT, ABC scale score increased by 1.2% [B (SE) = 0.04 (0.01), $p < 0.001$]. Together, BDI, and the 6-MWT explained 44% of the variability in the ABC scale scores (Table 4).

Discussion

This study demonstrates age- and sex-related differences in balance outcome measures among individuals with COPD at risk of falls. Within this cohort, females had higher balance impairments and lower confidence to perform functional activities than males with COPD. Advanced age was moderately associated with poor balance control and weakly with balance confidence. These age and sex differences in balance outcomes justify the potential importance of balance retraining for optimizing pulmonary rehabilitation and falls prevention programs in individuals with COPD. However, after controlling for the effect of balance risk factors such as dyspnea and exercise tolerance levels, age and sex were important factors for predicting balance impairments but not balance confidence. These results indicate that when designing balance training programs, dyspnea and exercise tolerance levels should be considered to obtain better treatment outcomes.

COPD does aggravate balance deficits, through a combination of altered postural activity of the trunk muscles [15], lower extremity muscle weakness, decreased levels of physical activity [16], and somatosensory deficits [19], and higher postural and functional balance impairments have been observed in individuals with COPD compared to healthy/control subjects [42–45]. Reduced exercise tolerance, gait speed, muscle force, and lung capacity, as well as the presence of comorbidities, history of exacerbations, and the use of oxygen therapy, are all potential risk factors underlying these balance impairments [42–45]. The higher balance deficits among females with COPD reported in the present

Table 4. A summary of regression models for balance measures in individuals with COPD.

	BBS, points		BEST test, %		ABC scale, %	
	Beta, *P*-value		Beta, *P*-value		Beta, *P*-value	
Predictors	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
Demographics:						
Age	−0.38, < 0.001	−0.27, < 0.001	−0.36, < .001	−0.21, < 0.001	−0.16, = 0.014	0.01, NS
Sex-male	−.22, < 0.001	−0.07, NS	−0.26, < .001	−0.14, < 0.02	−0.29, < 0.001	−0.05, NS
Falls history		−0.09, NS		−0.05, NS		−0.08, NS
Spirometry:						
FVC, L				−0.09, NS		0.11, NS
FVC%						0.02, NS
Comorbidities:						
Cardiac disease				−0.08, NS		
Hypertension						0.05, NS
Dyslipidemia						0.11, NS
GERD						0.08, NS
MSK conditions						−0.08, NS
Physiological measures:						
BDI		0.25, < 0.001		0.24, < 0.001		0.28, < 0.001
6-MWT		0.28, < 0.001		0.35, < 0.001		0.32, < 0.001
R^2	0.19	0.38	0.17	0.40	0.10	0.44
Adj R^2	0.18	0.36	0.17	0.38	0.09	0.41
Overall *F*	25.0	26.3	23.0	20.8	12.3	13.3
P-value	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001

Dependent variables: BBS, BEST test, and ABC scale.

Abbreviations: COPD: chronic obstructive pulmonary disease BBS: Berg balance scale; BEST test: balance evaluation system test; ABC: Activities-specific Balance Confidence Scale, NS: non-significant, FVC: forced vital capacity, GERD: Gastroesophageal Reflux Disease; MSK: musculoskeletal, BDI: baseline dyspnea index, 6-MWT: 6-min walk test.

study can be attributed to the more frequent use of oxygen therapy, reduced exercise tolerance, and decreased lung function. These findings are consistent with a previous report that noted worse balance control among community-dwelling older females. In that study, poor balance control was attributed to less effective proprioceptive control [46]. Besides, the decreased lung capacity in females was consistent with previous observations [9, 39]. In one study, lower lung function was associated with lower exercise tolerance [47]. Thus, we may attribute the poor exercise tolerance in females with COPD to the decreased FEV1 and FVC.

Impaired balance has been linked to an increased risk of falls among individuals with COPD [42], and the current study reported more frequent falls in the last one and two years among females with COPD. Possible factors that cause frequent falls in COPD include reduced balance confidence, older age, increased dyspnea, physical inactivity, reduced exercise tolerance, and muscle weakness [16, 17, 42]. In this study, females with COPD had reduced balance confidence and exercise tolerance, and increased balance impairments and dyspnea, all explain the increased number of falls among females with COPD. Previous research has linked the lower balance confidence to perform balance-related activities in females to less effective functioning in daily life and activity avoidance [48] with increased physical and mental health co-morbidities [6, 11]. Besides, a high prevalence of falls may cause reduced quality of life and increased mortality in individuals with COPD [42]. Thus, preserving balance function in those patients is important to sustain their quality of life and reduce the risk of falls, especially among females with COPD.

Several studies have documented that healthy older adults have more balance deficits than younger adults [15, 16]. Advanced age causes deterioration in the sensory systems and changes muscle activation leading to impaired balance in older adults [46, 49]. In avoiding falls, older adults tend to maintain higher stability while walking, unlike young adults who change walking speed or stride length [49]. We noted differences in stability limits and postural responses on the BEST test between older and younger adults, but these did not reach statistical significance. However, despite the higher balance deficits in older adults with COPD, the number of falls in the last one and two years were the same in both groups. Although age > 65 years is a known risk factor for falls, this might not be expressed because of the reduced physical activities among older adults, leading to less frequent falls [50].

Balance training combined with PR, fall prevention programs, Tai Chi, and cycling exercise have been shown to improve balance and fall risk in individuals with COPD [21, 22]. However, when designing balance training programs, dyspnea and exercise tolerance levels are important factors to consider in this population [21, 22, 51]. These considerations are consistent with the findings of our study showing the significant effect of these factors in predicting balance impairments and confidence to perform functional activities in COPD.

Strengths and limitations

This study has several strengths. It provides new information about age and sex differences in balance outcome measures among individuals with COPD at risk of falls. The data of this study were collected as part of a large international RCT (Canada, United Kingdom, Australia, and Portugal), which increases the external validity of the results. Additionally, balance impairments were evaluated using tools

that are valid and reliable for individuals with COPD [16, 17, 20].

This study also has limitations. Causation cannot be implied from cross-sectional and correlational analyses. Furthermore, the age and sex differences in the balance outcomes were small, and their clinical importance needs to be substantiated. Lastly, the sample size for the spirometry data was small ($n = 125$), which precluded further analysis that assesses age and sex differences in balance outcomes across COPD with different disease severity based on GOLD criteria. Future studies are needed to examine balance measures based on age, sex, and disease severity.

Conclusion

In individuals with COPD who are at risk of falls, females, and older adults (>65 years) had more balance impairments than males and younger adults. These observations have implications for pulmonary rehabilitation and fall prevention in this population, particularly among females and older individuals with COPD. We recommend taking age, sex, and dyspnea and exercise tolerance levels into account when planning balance training for individuals with COPD.

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Declaration of Interest

All authors declare no conflict of interest.

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